Optically Isolated HV/IGBT Megawatt Inverter Building Block for DER Applications

Low-cost Modular
Highly Reliable
Inverter
Development

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MW Inverter Project Goals

> Develop and test an advanced pre-production three phase, 5 megawatt inverter system based upon HV-IGBTs switches with complete optical isolation (control and sensing) between the high power subassemblies and the low power hardware.





Dual-Use Applications

- Emergency Power Markets
 - Short Term Ride Through Appl.
 - Longer Term UPS Applications
- Distributed Energy Markets
 - Advanced Power Conversion Technologies
 - Battery Manufacturers
 - ✓ Fuel Cell Manufacturers
 - ✓ Flywheel Manufacturers
 - ✓ Turbine Manufacturers
 - ✓ Solar Array Manufacturers

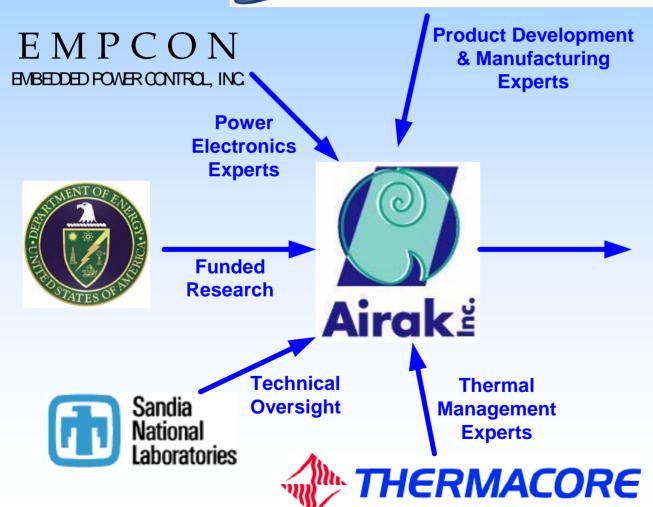
- Military Markets
 - Fuel Cell Applications
 - ✓ Submarines
 - Afloat Forces
 - Forward Deployed Forces
 - "All Electric" Ship
 - ✓ Zonal Power Distribution
 - ✓ Prime Mover Power Conversion
 - Electric (Land) Vehicles



Team Members







Modular Converter & Inverter Products

- Active Filters
- Back-to-Back
 Converters
- MV Direct
 Connect
- Leading VAR Controller



Why Go Optical?

- Optical Transducers and Interfaces Allow:
 - Intrinsic Galvanic / Electrical Isolation
 - EMI Immunity => Increased Reliability
 - Increased Equipment and Personnel Safety
 - All Fiber Optic Construction
 - Assembly Tested to 130 KV
 - Size is Invariant to Measurement Range







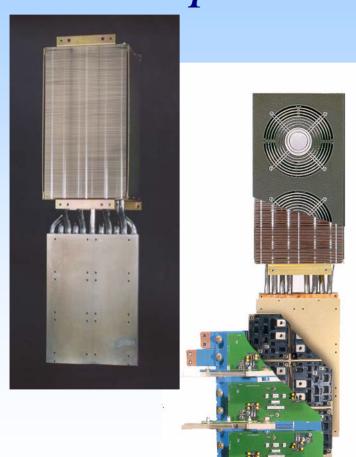
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Mitsubishi HV-IGBT Packages



- Common 190 x 140 mm Footprint
 - CM1200HA-34H : 1.7 KV, 1200A
 - CM1200HC-50H: 2.5 KV, 1200A
 - <u>CM1200HC-66H: 3.3 KV,</u> 1200A
 - CM900HB-90H: 4.5 KV, 900A
- Scaleable Phase Leg Designs Possible
- > Efficient Interface to Bus Bar
- Higher Frequency Switching (~ 5 KHz)

Therma-ChargeTM Multi-Kilowatt Heat Pipe Heat Sink



Power Rating: 10,000 watts (Modified Standard 835 Design)

Nom. Air Flow: 600 CFM per 2 Fans

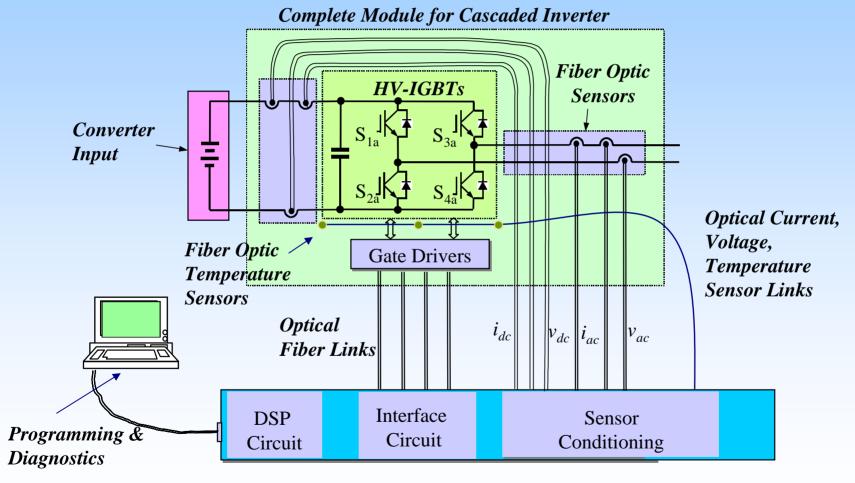
Working Fluid: Water

Operating Range: 40° C – 180° C

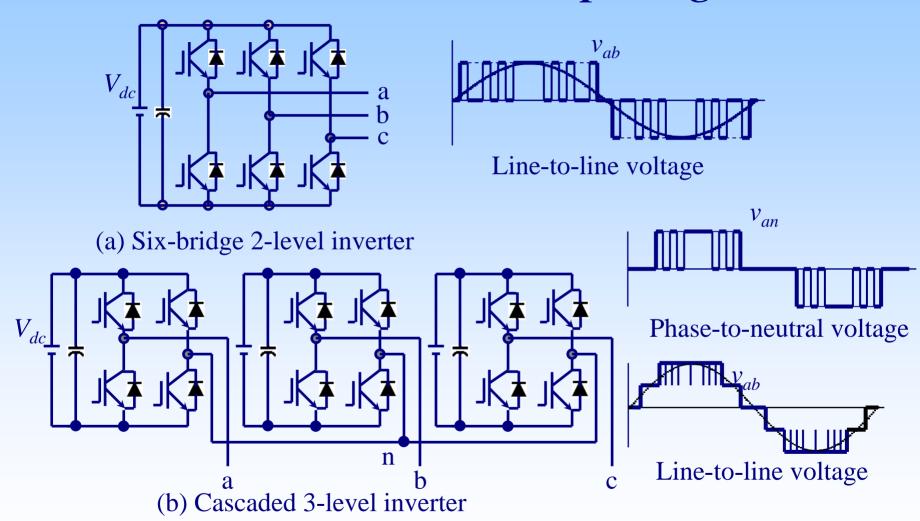
New Design Tested to $\Delta 43^{\circ}$ C at 8250W True Power Dissipation



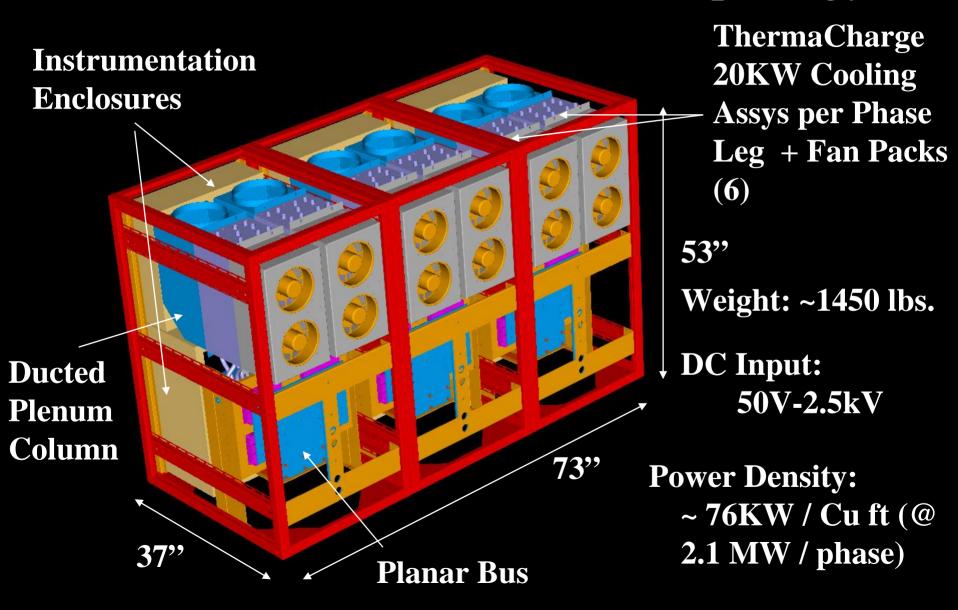
Single Phase Building Block Sensor & Control Configuration



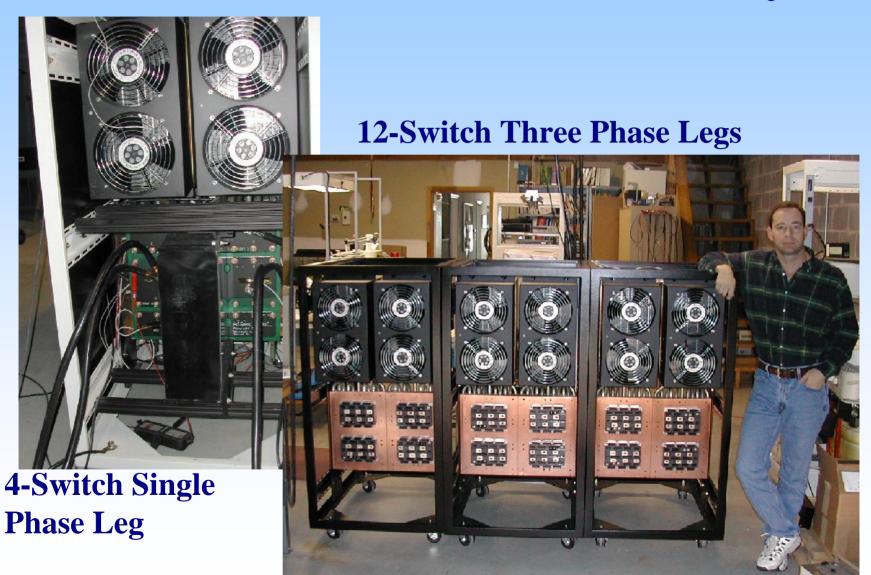
Inverter Circuit Topologies



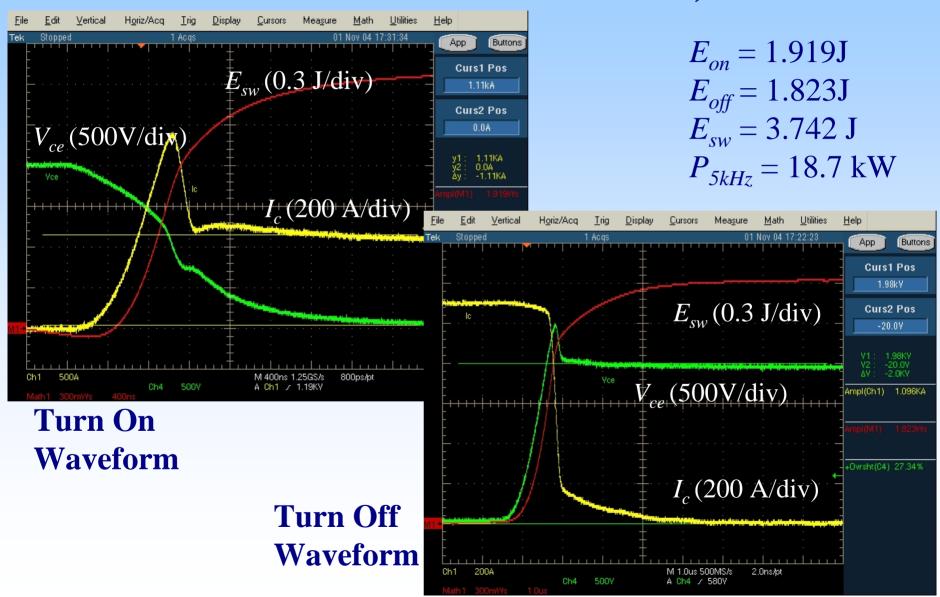
6-MW 3-Phase Inverter Topology



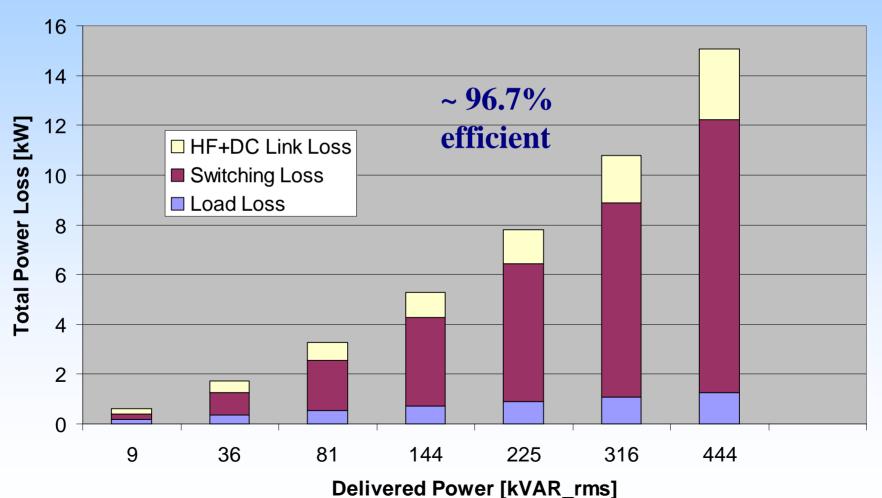
3-Phase 12-Switch Inverter Size



HV-IGBT Switched at 2 kV, 1100 A

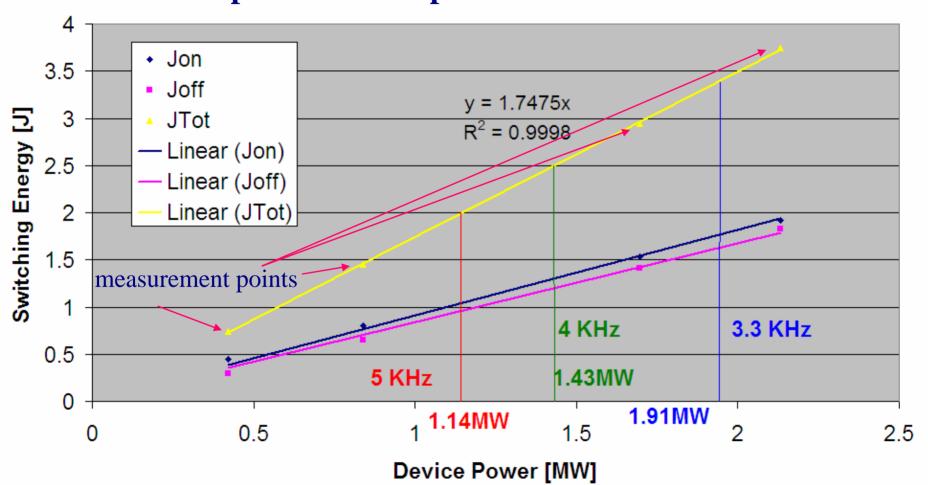


Single Phase System Power Loss vs. Power Delivered

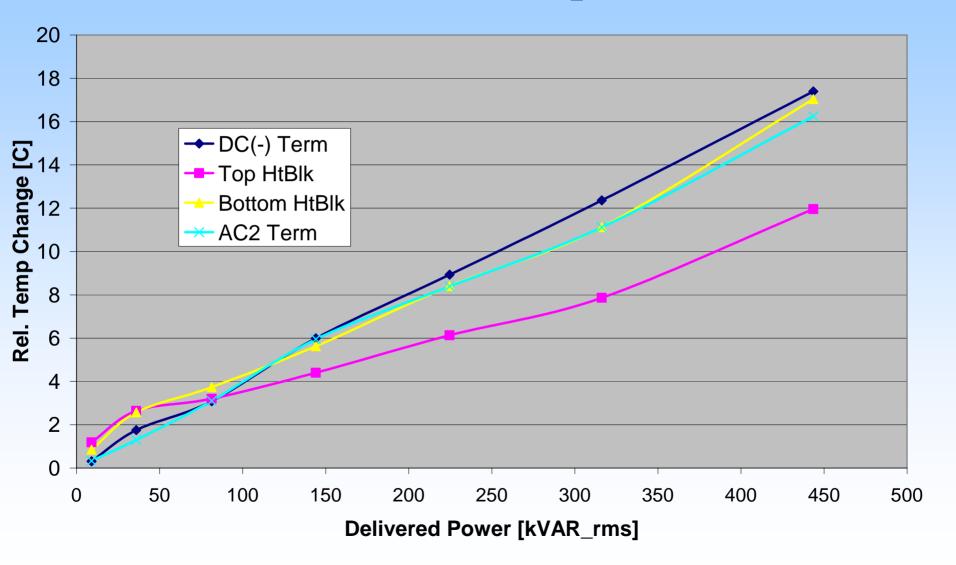


6-Switch Power Loss Boundaries

10 KW Heat Pipe Restriction per Switch Pair



MW Inverter Temperatures



Modular Inverter Project Goals

- > Develop standardized 200kW and 1MW power electronic modules for converter/inverter applications.
- > Demonstrate modular converters/inverters in various configurations to prove the viability of standarized power converter components for multiple and diverse applications.
- > New program; just turned on October 2004

The Need for Modular Building Blocks

- > There exist few cost-effective, efficient, & reliable power conversion topologies for high-power markets.
- > Equipment is tailored to the application, driving costs upward.
- > Standardized modules simplify maintenance, lower spares/inventory costs, and reduce system complexity.

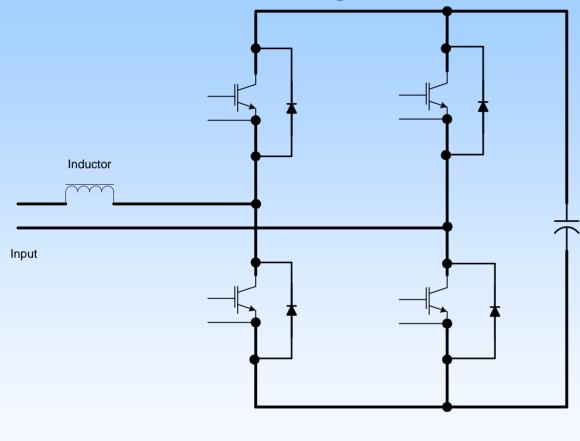


"Modular" Program Approach

- > Two Parallel Paths
 - MW Converters
 - ✓ Heat-Pipe
 - ✓ Optically Isolated
 - ✓ PowerEx IGBTs
 - 200 KW Converters
 - ✓ Air Cooled
 - ✓ Optical Gate Drives(?) Conventional Sensors
 - ✓ Semikron SemiTrans IGBTs

- Three Demonstrations per Path
 - VAR Compensator
 - Active Filter
 - Back-to-Back

Leading VAR Controller



VAR Regulator

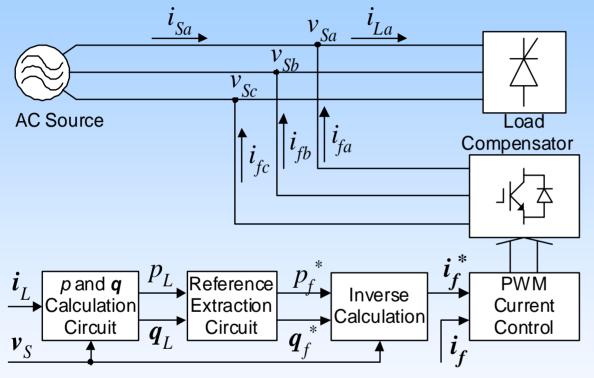
Advantages

- Produces Steady State Leading
 VARs (Offset
 Lagging VARs
 from Motors and
 Inductive Loads)
- Reduce VoltageDistortion
- Stabilize LocalPower Grid

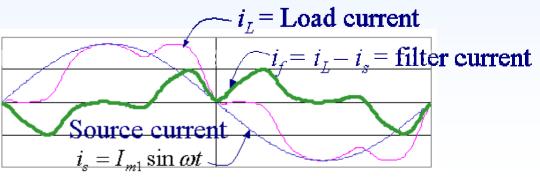
Active Filtering



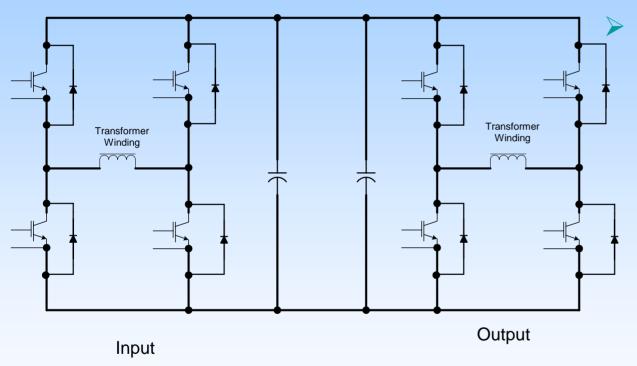




- Restores pf to 1
- Provides ~ 10x
 Reactive
 Compensation
 from Real Power
 Size (100 KW
 1MVAR)
- Market Demand is Increasing



Back-to-Back Config



Advantages

- Draws SinusoidalCurrent at pf ~ 1
- AllowsBidirectonalPower Flow
- High OutputCapability (scales to MW or KW blocks)

Summary

- MW building blocks achieved and being configured for leading-VAR demo (1st "low fruit")
- MW program created two technologies, one which has received two significant awards and two issued/one pending patents
- MW program has generated nearly \$2.5M in Government (U.S. Navy) acquisition revenue.

- KW program will use aircooling over heat block design
- KW program will use same manufacturing concepts developed during MW program (modeling, modularity, etc.)
- KW program will compare/contrast cost, complexity, reliability, and performance of KW and MWscale converters in three different applications.

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